

## 5.2.6 Ground-Source Heat Pumps

Heat pumps function by moving (or pumping) heat from one place to another. Like a standard air-conditioner, a heat pump takes heat from inside a building and dumps it outside. The difference is that a heat pump can be reversed to take heat from a heat source outside and pump it inside. Heat pumps use electricity to operate pumps that alternately evaporate and condense a refrigerant fluid to move that heat. In the heating mode, heat pumps are far more “efficient” at converting electricity into usable heat because the electricity is used to *move* heat, not to generate it.

The most common type of heat pump—an air-source heat pump—uses outside air as the *heat source* during the heating season and the *heat sink* during the air-conditioning season. *Ground-source* and *water-source* heat pumps work the same way, except that the heat source/sink is the ground, groundwater, or a body of surface water, such as a lake. (For simplicity, water-source heat pumps are often lumped with ground-source heat pumps, as is the case here.) The efficiency or *coefficient of performance* of ground-source heat pumps is significantly higher than that of air-source heat pumps because the heat source is warmer during the heating season and the heat sink is cooler during the cooling season. Ground-source heat pumps are also known as *geothermal* heat pumps, though this is a bit of a misnomer since the ultimate heat source with most ground-source heat pumps is really solar energy—which maintains the long-term earth temperatures within the top few meters of the ground surface. Only deep-well ground-source heat pumps that benefit from much deeper earth temperatures may be actually utilizing geothermal energy.

Ground-source heat pumps are environmentally attractive because they deliver so much heat or cooling energy per unit of electricity consumed. The COP is usually 3 or higher. The best ground-source heat pumps are more efficient than high-efficiency gas combustion, even when the *source efficiency* of the electricity is taken into account.

### Opportunities

Ground-source heat pumps are generally most appropriate for residential and small commercial buildings,

such as small-town post offices. In residential and small (skin-dominated) commercial buildings, ground-source heat pumps make the most sense in mixed climates with significant heating and cooling loads because the high-cost heat pump replaces both the heating and air-conditioning system. In larger buildings (with significant internal loads), the investment in a ground-source heat pump can be justified further north because air-

conditioning loads increase with building size. *Packaged terminal heat pumps*, used in hotels and large apartment buildings, are similar except that the heat source is a continuously circulating source of chilled water—the individual water-source heat pumps provide a fully controllable source of heat or air-conditioning for individual rooms.

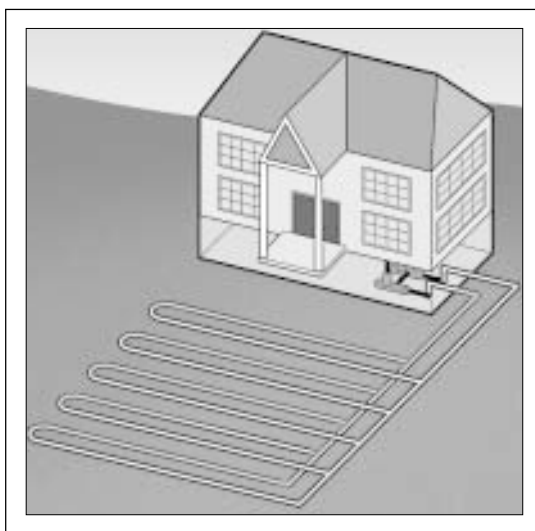
Because ground-source heat pumps are expensive to install in residential and small commercial buildings, it sometimes makes better economic sense to invest in energy efficiency measures that significantly reduce heating and cooling loads, then install less expensive heating and cooling equipment—the savings in equipment may be able to pay

for most of the envelope improvements (see *Section 4.1 – Integrated Building Design*). If a ground-source heat pump is to be used, plan the site work and project scheduling carefully so that the ground loop can be installed with minimum site disturbance or in an area that will be covered by a parking lot or driveway.

### Technical Information

Ground-source heat pumps are generally classified according to the type of loop used to exchange heat with the heat source/sink. Most common are closed-loop horizontal (see the illustration above) and closed-loop vertical systems. Using a body of water as the heat source/sink is very effective, but seldom available as an option. Open-loop systems are less common than closed-loop systems due to performance problems (if detritus gets into the heat pump) and risk of contaminating the water source or—in the case of well water—inadequately recharging the aquifer.

Ground-source heat pumps are complex. Basically, water or a nontoxic antifreeze-water mix is circulated through buried polyethylene or polybutylene piping.



*Horizontal-loop ground-source heat pumps typically have tubing buried within the top 10 feet (3 m) of ground.*

Source: Al Paul Lefton Company

This water is then pumped through one of two heat exchangers in the heat pump. When used in the heating mode, this circulating water is pumped through the cold heat exchanger, where its heat is absorbed by evaporation of the refrigerant. The refrigerant is then pumped to the warm heat exchanger, where the refrigerant is condensed, releasing heat in the process. This sequence is reversed for operation in the cooling mode.

Direct-exchange ground-source heat pumps use copper ground-loop coils that are charged with refrigerant. This ground loop thus serves as one of the two heat exchangers in the heat pump. The overall efficiency is higher because one of the two separate heat exchangers is eliminated, but the risk of releasing the ozone-depleting refrigerant into the environment is greater. DX systems have a small market share.



**Free Hot Water:** When used in the cooling mode, a ground-source heat pump with a *desuperheater* will provide free hot water. Buildings in more southern climates that use a ground-source heat pump primarily for cooling can obtain a high percentage of hot water demand in this manner. Look for a ground-source heat pump that includes a *desuperheater* module.



**Typical system efficiencies and costs** of a number of heating, cooling, and water-heating systems for residential and light commercial buildings are shown in the table below (from EPA, 1993). Of all the systems listed, ground-source heat pumps are the most expensive to install but the least expensive to operate.



**Improving Performance:** There are a number of ways to improve ground-source heat pump performance. Cooling-tower-supplemented systems can reduce the total size of the ground loop required to meet cooling demand. A cooling tower is added to the ground-coupled loop by means of a heat exchanger. Solar-assisted systems use solar energy to supplement heating in northern climates. Solar panels boost the temperature of the ground loop.

## References

*Space Conditioning: The Next Frontier*, U.S. Environmental Protection Agency, Washington, DC, 1993.

*Space Heating Technology Atlas*, E Source, Inc., Boulder, CO, 1996; (303) 440-8500; [www.esource.com](http://www.esource.com).

*GeoExchange in Federal Facilities*, Geothermal Heat Pump Consortium (see contact information below).

Malin, Nadav, and Alex Wilson, "Ground-Source Heat Pumps: Are They Green?" *Environmental Building News*, Vol. 9, No. 7/8, July 2000; BuildingGreen, Inc., Brattleboro, VT; (800) 861-0954; [www.BuildingGreen.com](http://www.BuildingGreen.com).

## Contacts

Geothermal Heat Pump Consortium, 701 Pennsylvania Avenue, NW, Washington, DC 20004; (888) 255-4436, (202) 508-5500, (202) 508-5222 (fax); [www.geoexchange.org](http://www.geoexchange.org).

U.S. Department of Energy; [www.eren.doe.gov/](http://www.eren.doe.gov/) or [www.energy.gov](http://www.energy.gov).

## SEASONAL PERFORMANCE FACTORS<sup>(1)</sup>

Space-Conditioning System	Heating	Cooling	Hot Water	Installed Cost	Ann. Op. Cost
Electric resistance with elec. A/C	1.00	2.3–2.6	0.90	\$5,415–5,615	\$871–2,945
Gas furnace with elec. A/C	0.64–0.87	2.3–3.2	0.56–0.60	\$5,775–7,200	\$461–1,377
Adv. oil furnace with elec. A/C	0.73	3.1–3.2	0.90	\$6,515	\$1,162–1,370
Air-source heat pump	1.6–2.9	2.3–4.3	0.90–3.1	\$5,315–10,295	\$353–2,059
Ground-source heat pump	2.7–5.4	2.8–6.0	1.2–3.0	\$7,520–10,730	\$274–1,179
1. Seasonal performance factors represent seasonal efficiencies for conventional heating and cooling systems and seasonal COPs for heat pumps. Ranges show modeled performance by EPA in different climates.					

Source: U.S. Environmental Protection Agency, *Space Conditioning: The Next Frontier*, 1993